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AN
ESSAY^k

ON THE
USEFULNESS
OF
Mathematical Learning.

IN A
LETTER

FROM
A GENTLEMAN in the *CITY*, to his
FRIEND at *OXFORD*.

THE THIRD EDITION.



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A N
E S S A Y
O N T H E
U S E F U L N E S S
O F
M A T H E M A T I C A L L E A R N I N G, &c.

S I R,

I AM glad to hear from you, that the Study of the *Mathematics* is Promoted and Encouraged among the *Youth* of your *University*. The great Influence, which these *Sciences* have on Philosophy, and all useful Learning, as well as the Concerns of the Public, may sufficiently recommend them to your Choice and Consideration: And the particular Advantages, which You of that Place enjoy, give Us just Reason to expect from You a suitable Improvement in them. I have here sent you some short Reflections upon the *Usefulness* of *Mathematical Learning*, which may serve as an Argument to incite you to a closer and more vigorous Pursuit of it.

In all Ages and Countries, where Learning hath prevailed, the *Mathematical Sciences* have been looked upon as the most considerable Branch of it. The very Name *Μαθηματικά* implies no less; by which they were called, either for their Excellency; or because, of all the *Sciences*, they were first taught; or because they were judged to comprehend *πάντα*

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τὰ Μαθηματῶν. And, amongst those, that are commonly reckoned to be the Seven Liberal Arts, Four are Mathematical, to wit, *Arithmetic, Music, Geometry, and Astronomy.*

X But, notwithstanding their Excellency and Reputation, they have not been taught nor study'd so universally, as some of the rest; which I take to have proceeded from the following Causes: The *Aversion of the greatest Part of Mankind to serious Attention, and close Arguing; Their not comprehending sufficiently the Necessity, or great Usefulness, of these in other Parts of Learning; An Opinion that this Study requires a particular Genius and Turn of Head, which few are so happy as to be born with; And the Want of public Encouragement, and able Masters.* For these, and perhaps some other Reasons, this Study hath been generally neglected, and regarded only by some few Persons, whose happy Genius and Curiosity have prompted them to it, or who have been forced upon it by its immediate Subserviency to some particular Art or Office.

Therefore I think I cannot do better Service to Learning, Youth, and the Nation in general, than by shewing, *That the Mathematics, of all Parts of human Knowledge, for the Improvement of the Mind, for their Subserviency to other Arts, and their Usefulness to the Commonwealth, deserve most to be encouraged.* I know a Discourse of this Nature will be offensive to some, who, while they are ignorant of Mathematics, yet think themselves Masters of all valuable Learning: But their Displeasure must not deter me from delivering an useful Truth.

X The Advantages which accrue to the Mind by Mathematical Studies, consist chiefly in these Things: 1st, In accustoming it to *Attention.* 2dly, In giving it a Habit of *close and demonstrative Reasoning.* 3dly, In freeing it from *Prejudice, Credulity, and Superstition.*

First,

First, the Mathematics make the Mind attentive to the Objects, which it considers. This they do by entertaining it with a great Variety of Truths, which are delightful and evident, but not obvious. Truth is the same thing to the Understanding, as Music to the Ear, and Beauty to the Eye. The Pursuit of it does really as much gratify a natural Faculty implanted in us by our wise Creator, as the pleasing of our Senses: Only in the former Case, as the Object and Faculty are more spiritual, the Delight is the more pure, free from the Regret, Turpitude, Lassitude, and Intemperance, that commonly attend sensual Pleasures. The most Part of other Sciences consisting only of probable Reasonings, the Mind has not where to fix; and, wanting sufficient Principles to pursue its Searches upon, gives them over as impossible. ~~Again~~, as in *Mathematical Investigations* Truth may be found, ~~so~~ it is not always obvious: ~~This~~ spurs the Mind, and makes it diligent and attentive. In *Geometria* (says *Quintilian*, lib. I. cap. 10.) *partem fatentur esse utilem teneris ætatibus: agitari namque animos, atque acui ingenia, & celeritatem percipiendi venire inde concedunt.* And *Plato* (in *Repub.* lib. VII.) observes, that the Youth, who are furnished with *Mathematical* Knowledge, are prompt and quick at all other Sciences, *ὡς πάντα τὰ μαθηματικά οὕτως φαίνονται.* Therefore he calls it *καὶ ἀπαιδείαν ὀδόν.* And, indeed, Youth is generally so much more delighted with *Mathematical* Studies, than with the unpleasant Tasks, that are sometimes imposed upon them, that I have known some reclaimed by them from Idleness, and Neglect of Learning; and acquire in time a Habit of Thinking, Diligence, and Attention; Qualities, which we ought to study by all means to beget in their desultory and roving Minds.

The Second Advantage, which the Mind reaps from *Mathematical* Knowledge, is a Habit of clear, demonstrative, and methodical Reasoning. We are

contrived

contrived by Nature to learn by Imitation more than by Precept: And, I believe, in that respect, Reasoning is much like other inferior Arts (as ~~Dancing, Singing, &c.~~) acquired by Practice. By accustoming ourselves to reason closely about Quantity, we acquire a Habit of doing so in other things. It is surprising to see, what superficial inconsequential Reasonings satisfy the most Part of Mankind. A Piece of Wit, a Jest, a Simile, or a Quotation of an Author, passes for a mighty Argument: With such things as these are the most Part of Authors stuffed; and from these weighty Premises they infer their Conclusions. This Weakness and Effeminacy of Mankind in being persuaded where they are delighted, have made them the Sport of Orators, Poets, and Men of Wit. Those *lumina orationis* are indeed very good Diversion for the Fancy, but are not the proper Business of the Understanding; and where a Man pretends to write on abstract Subjects in a scientific Method, he ought not to debauch in them. Logical Precepts are ~~not~~ useful, nay, they are absolutely necessary, for a Rule of formal Arguing in public Disputations, and confounding an obstinate and perverse Adversary, and exposing him to the Audience or Readers. But, in the Search of Truth, an Imitation of the Method of the Geometers will carry a Man farther than all the *Dialectical* Rules. Their *Analysis* is the proper Model we ought to form ourselves upon, and imitate in the regular Disposition, and gradual Progress, of our Inquiries; and even he, who is ignorant of the Nature of *Mathematical Analysis*, uses a Method somewhat analogous to it. ~~The Composition of the~~ *Geometers*, or their Method of demonstrating Truths already found out, viz. by Definitions of Words agreed upon, by self-evident Truths, and Propositions that have been already demonstrated, is practicable in other Subjects, tho' not to the same Perfection, the natural
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Want of Evidence in the things themselves not allowing it; but it is imitable to a considerable Degree. I dare appeal to some Writings of our own Age and Nation, the Authors of which have been mathematically inclined. I shall add no more on this Head, but, that one, who is accustomed to the methodical Systems of Truths, which the *Geometers* have reared up in the several Branches of those *Sciences*, which they have cultivated, will hardly bear with the Confusion and Disorder of other *Sciences*, ~~but endeavour, as far as he can, to reform them.~~

Thirdly, *Mathematical* Knowledge adds a manly Vigour to the Mind, frees it from *Prejudice*, *Credulity*, and *Superstition*. This it does two Ways: 1st, By accustoming us to examine, and not to take things upon Trust. 2dly, By giving us a clear and extensive Knowledge of the System of the World; which, as it creates in us the most profound Reverence of the almighty and wise Creator; ~~so it~~ ^{will naturally} free us from the mean and narrow Thoughts, ~~which~~ ^{that} Ignorance and Superstition are apt to beget. How great an Enemy *Mathematics* are to Superstition, appears from this, That in those Countries, where *Romish* Priests exercise their barbarous Tyranny over the Minds of Men, *Astronomers*, who are fully persuaded of the Motion of the Earth, dare not speak out: But tho' the *Inquisition* may extort a Recantation, the Pope, and a general Council too, will not find themselves able to persuade to the contrary Opinion. Perhaps, this may have given Occasion to a calumnious Suggestion, as if *Mathematics* were an Enemy to Religion, which is a Scandal thrown both on the one and the other; for Truth can never be, an Enemy to true Religion, which appears always to the best Advantage, when it is most examined.

————— *Si propius stes,*
Te capiet magis. —————

On

On the contrary, the *Mathematics* are Friends to Religion; inasmuch as they charm the Passions, restrain the Impetuosity of Imagination, and purge the Mind from Error and Prejudice. Vice is Error, Confusion, and false Reasoning; and all Truth is more or less opposite to it. Besides, *Mathematical* Studies may serve for a pleasant Entertainment for those Hours, which young Men are apt to throw away upon their Vices; the Delightfulness of them being such, as to make Solitude not only easy, but desirable.

X What I have said may serve to recommend *Mathematics* for acquiring a vigorous Constitution of Mind; for which Purpose they are as useful, as Exercise is for procuring Health and Strength to the Body. I proceed now to shew their vast Extent and Usefulness in other Parts of Knowledge. And here it might suffice to tell you, that *Mathematics* is the *Science* of Quantity, or the *Art* of Reasoning about things that are capable of *More* and *Less*; and that the most Part of the Objects of our Knowledge are such; as Matter, Space, Number, Time, Motion, Gravity, &c. We have but imperfect Ideas of Things without Quantity, and as imperfect a one of Quantity itself without the Help of *Mathematics*. All the visible Works of God Almighty are made in *Number*, *Weight*, and *Measure*: Therefore, to consider them, we ought to understand *Arithmetic*, *Geometry*, and *Statics*: And the greater Advances we make in those Arts, the more capable we are of considering such things, as are the ordinary Objects of our Conceptions. But this will farther appear from Particulars.

And, first, if we consider, to what Perfection we now know the Courses, Periods, Order, Distances, and Proportions of the several great Bodies of the Universe, at least, such as fall within our View; we shall have Cause to admire the Sagacity and Industry

dustry of the *Mathematicians*; and the Power of *Numbers* and *Geometry* well applied. Let us cast our Eyes backward, and consider *Astronomy* in its Infancy: Or rather let us suppose it still to begin: For Instance; a Colony of rude Country People, transplanted into an Island remote from the Commerce of all Mankind, without so much as the Knowledge of the Kalendar, and the Periods of the Seasons, without Instruments to make Observations, or any the least Notion of Observations or Instruments. When is it we could expect any of their Posterity should arrive at the Art of predicting an Eclipse? Not only so, but the Art of reckoning all Eclipses that are past or to come, for any Number of Years? When is it we could suppose, that one of those Islanders, transported to any other Place of the Earth, should be able, by the Inspection of the Heavens, to find how much he were South or North, East or West of his own Island, and to conduct his Ship back thither? For my Part, tho' I know this may be and is daily done, by what is known in *Astronomy*; yet when I consider the vast Industry, Sagacity, Multitude of Observations, and other extrinsic Things necessary for such a sublime Piece of Knowledge, I should be apt to pronounce it impossible, and never to be hoped for. Now we are let so much into the Knowledge of the Machine of the Universe, and Motion of its Parts, by the Rules of this *Science*, perhaps the Invention may seem easy. But when we reflect, what Penetration and Contrivance were necessary to lay the Foundations of so great and extensive an Art, we cannot but admire its first Inventors: As *Thales Milesius*, who, as *Dio- geneses Laertius* and *Pliny* say, first predicted Eclipses; and his Scholar *Anaximander Milesius*, who found out the globous Figure of the Earth, the Equinoctial Points, the Obliquity of the Ecliptic, the Principles of Gnomonics, and made the first Sphere

probable, spend more than 2000 Years in one Revolution about the Sun; for whose Theory he has laid such a Foundation, that after Ages, assisted with more Observations, may be able to calculate their Returns. In a Word, the Procession of the Equinoctial Points, the Tides, the unequal Vibration of pendulous Bodies in different Latitudes, &c. are no more a Question to those, that have *Geometry* enough to understand what he has delivered on those Subjects: A Perfection in *Philosophy*, that the boldest Thinker durst hardly have hoped for; and, unless Mankind turn barbarous, will continue the Reputation of this Nation, as long as the Fabric of Nature shall endure. After this, what is it we may not expect from *Geometry*, joined to *Observations* and *Experiments*?

The next considerable Object of Natural Knowledge, I take to be *Light*. How unsuccessful Inquiries are about this glorious Body without the Help of *Geometry*, may appear from the empty and frivolous Discourses and Disputations of a Sort of Men, that call themselves *Philosophers*; whom nothing will serve, ~~forsooth~~, but the Knowledge of the very Nature, and intimate Causes, of every thing: While, on the other hand, the *Geometers*, not troubling themselves with those fruitless Inquiries about the Nature of *Light*, have discovered Two remarkable Properties of it, in the Reflexion and Refraction of its Beams: And from those, and their Streightness in other Cases, have invented the noble Arts of *Optics*, *Catoptrics*, and *Dioptrics*; teaching us to manage this subtile Body for the Improvement of our Knowledge, and useful Purposes of Life. They have likewise demonstrated the Causes of several celestial Appearances, that arise from the Inflexion of its Beams, both in the heavenly Bodies themselves, and other Phænomena, as *Parbelia*, the *Iris*, &c. and by a late Experiment they have

discovered the Celerity of its Motion. And we shall know yet more surprizing Properties of *Light*, when Mr. *Newton* shall be pleased to gratify the World with his *Book of Light and Colours*.

The *Fluids* which involve our Earth, viz. *Air* and *Water*, are the next great and conspicuous Bodies, that Nature presents to our View: And, I think, we know little of either, but what is owing to *Mechanics* and *Geometry*. The Two chiefeft Properties of *Air*, its Gravity, and elastic Force, have been discovered by Mechanical Experiments. From thence the Decrease of the Air's Density, according to the Increase of the Distance of the Earth, has been demonstrated by *Geometers*, and confirmed by Experiments of the Subsidence of the *Mercury* in the *Toricellian Experiment*. From this likewise, by Assistance of *Geometry*, they have determined the Height of the Atmosphere, as far as it has any sensible Density; which agrees exactly with another Observation of the Duration of the Twilight. *Air* and *Water* make up the Object of the *Hydrostatics*, tho' denominated only from the latter, of which the Principles were long since settled and demonstrated by *Archimedes*, in his Book *περὶ τῶν ὀχυμένων*, where are demonstrated the Causes of several surprizing Phænomena of Nature, depending only on the *Æquilibrium* of *Fluids*, the relative Gravities of these *Fluids*, and of Solids swimming or sinking therein. Here also the Mathematicians consider the different Pressures, Resistances, and Celerities of Solids moved in *Fluids*: From whence they explain a great many Appearances of Nature, unintelligible to those who are ignorant of *Geometry*.

Next, if we descend to the *Animal Kingdom*, there we may see the brightest Strokes of Divine *Mechanics*. And whether we consider first the *Animal Oeconomy* in general, either in the internal Motion and Circulation of the Juices forced through the
several

several Canals by the Motion of the Heart, or their external Motions, and the Instruments wherewith these are performed, we must reduce them to Mechanical Rules, and confess the Necessity of the Knowledge of Mechanics to understand them, or explain them to others. *Borelli* in his excellent Treatise *de Motu Animalium*, *Steno* in his admirable *Myologia Specimen*, and other Mathematical Men, on the one hand, and the nonsensical, unintelligible Stuff that the common Writers on these Subjects have filled their Books with, on the other, are sufficient Instances to shew, how necessary *Geometry* is in such Speculations. The only Organ of an Animal Body, whose Structure and Manner of Operation is fully understood, has been the only one, which the *Geometers* have taken to their Share to consider. It is incredible, how sillily the greatest and ablest Physicians talked of the Parts of the Eye and their Use, and of the *Modus Visionis*, before *Kepler* by his *Geometry* found it out, and put it past Dispute, that they applied themselves particularly to this, and valued themselves on it: And *Galen* pretended a particular Divine Commission to treat of it. Nay, notwithstanding the full Discovery of it, some go on in copying their Predecessors, and talk as *Ungeometrically* as ever. It is true, we cannot reason so clearly of the internal Motions of an Animal Body, as of the external, wanting sufficient *Data*, and decisive Experiments: But what relates to the latter (as the Articulation, Structure, Insertion, and *Vires* of the Muscles) is as subject to strict Mathematical Disquisition, as any thing whatsoever; and even in the Theory of Diseases, and their Cures, those, who talk Mechanically talk most intelligibly. Which may be the Reason for the Opinion of the antient Physicians, that Mathematics are necessary for the Study of the Medicine itself, for which I ~~could bring~~ long Quotations out
of

of their Works. Among the Letters that are ascrib'd to *Hippocrates*, there is one to his Son *Thessalus*, recommending to him the Study of *Arithmetic* and *Geometry*, as necessary to Medicine. *Galen* in his Book, intituled, ὅτι αἰετος ἰατρὸς καὶ φιλόσοφος, begins,

Οἷόν τι πεπόνθασιν οἱ πολλοὶ τῶν ἀθλητῶν, ἐπιθυμῶντες μὲν Ὀλυμπιονίκαι γενέσθαι, μηδὲν δὲ πράττειν, ὥς τέτε τυχεῖν, ἐπιηδύοντες, τοιούτων τι καὶ τοῖς πολλοῖς τῶν ἰατρῶν συμβέβηκεν· ἐπαινεῖσι μὲν γὰρ Ἱπποκράτην, καὶ πρῶτον ἀπάντων ἡγήσασθαι γενέσθαι δὲ αὐτὸς ἐν ὁμοίοις ἐκείνῳ πάντα μᾶλλον ἢ τὰτο πράττεισι· οἱ μὲν γὰρ ἐ μικρὴν μοῖραν εἰς ἰατρικὴν φησι συμβάλλεσθαι τὴν ἀστρονομίαν, καὶ δηλοῦσι, τὴν ταύτης ἡγεμένην εἶ ἀνάγκης γεωμετρίαν· οἱ δὲ ἐ μόνον αὐτοὶ μέλρονται τέτων ἐδέτερον, ἀλλὰ καὶ τοῖς μέλλουσιν μέμρονται. If one of the Reasons of the Antients for this be now somewhat unfashionable, to wit, because they thought a Physician should be able to know the Situation and Aspects of the Stars, which they believed had Influence upon Men and their Diseases, (and positively to deny it, and say, that they have none at all, is the Effect of Want of Observation) we have a much better and undoubted one in its room; viz. That Mathematics are found to be the best Instrument of promoting Natural Knowledge. 2dly, If we consider, not only the Animal Oeconomy in general, but likewise the wonderful Structure of the different Sorts of Animals, according to the different Purposes for which they were design'd, the various Elements they inhabit, the several Ways of procuring their Nourishment, and propagating their Kind, the different Enemies they have, and Accidents they are subject to, here is still a greater Need of *Geometry*. It is pity, that the Qualities of an expert *Anatomist* and skillful *Geometer*, have seldom met in the same Person. When such a one shall appear, there is a whole *Terra incognita* of delightful Knowledge to employ his Time, and reward his Industry.

As for the other two Kingdoms; *Borelli*, and other *Mathematical Men*, seem to have talked very clearly of *Vegetation*: And *Steno*, another Mathematician, in his excellent Treatise *de Solido intra Solidum naturaliter contento*, has apply'd this Part of Learning very handsomely to *Fossils*, and some other Parts of Natural History. I shall add only one thing more, That if we consider Motion itself, the great Instrument of the Actions of Bodies upon one another, the Theory of it is intirely owing to the *Geometers*; who have demonstrated its Laws both in hard and elastic Bodies; shewed how to measure its Quantity, how to compound and resolve the several Forces, by which Bodies are agitated, and to determine the *Lines*, which those compound Forces make them describe: Of such Forces Gravity, being the most constant and uniform, affords a great Variety of useful Knowledge, in considering several Motions that happen upon the Earth; *viz.* As to the free Descent of heavy Bodies; The Curve of Projectiles; The Descent and Weight of heavy Bodies, when they lie on inclined Planes; The Theory of the Motion of pendulous Bodies, &c.

From what I have said, I shall draw but one Corollary, That a Natural Philosopher without Mathematics is a very odd Sort of a Person, that reasons about things that have *Bulk*, *Figure*, *Motion*, *Number*, *Weight*, &c. without *Arithmetic*, *Geometry*, *Mechanics*, *Statics*, &c. I must needs say, I have the last Contempt for those Gentlemen, that pretend to explain how the Earth was framed, and yet can hardly measure an Acre of Ground upon the Surface of it: And as the Philosopher speaks, *Qui repente pedibus illotis ad Philosophos divertunt, non hoc est satis, quod sint omnino, ἀδελφοί, ἀμύστοι, ἀγρομέτρητορ* sed legem etiam dant, quā Philosophari discant.

The Usefulness of *Mathematics* in several other Arts and Sciences is fully as plain. They were looked upon

upon by the antient Philosophers as to the Key to all Knowledge. Therefore *Plato* wrote upon his School, Οὐδεὶς ἀγεωμέτρητος εἰσὶτω, *Let none unskilled in Geometry enter*; and *Xenocrates* told one ignorant in *Mathematics*, who desired to be his Scholar, that he was fitter to card Wool, λαβὰς γὰρ ἔν ἔχεις φιλοσοφίας, *You want the Handle of Philosophy*, viz. *Geometry*. There is no understanding the Works of the antient Philosophers without it. *Theo. Smyrnæus* has wrote a Book, intituled, An Explanation of those things in *Mathematics*, that are necessary for the Reading of *Plato*: *Aristotle* illustrates his Precepts, and other Thoughts, by Mathematical Examples; and that not only in *Logic*, &c. but even in *Ethics*, where he makes use of Geometrical and Arithmetical Proportion, to explain commutative and distributive Justice.

Every body knows, that *Chronology* and *Geography* are indispensable Preparations for *History*; a Relation of Matter of Fact being a very lifeless insipid thing, without the Circumstances of Time and Place. Nor is it sufficient for one, that would understand things thoroughly, that he knows the Topography, that is, the Name of the Country, where such a Place lies, with those of the near adjacent Places, and how these lie in respect of one another; but it will become him likewise to understand the scientific Principles of the Art: that is, to have a true Idea of a Place, we ought to know the Relation it has to any other Place, as to the Distance and Bearing, its Climate, Heat, Cold, Length of Days, &c. which things do much enliven the Reader's Notion of the very Action itself. Just so, it is necessary to know the technical or doctrinal Part of *Chronology*, if a Man would be thoroughly skilled in *History*, it being impossible, without it, to unravel the Confusion of *Historians*. I remember Mr. *Halley* has determined the

the Day and Hour of *Julius Cæsar's* Landing in *Britain*, from the Circumstances of his Relation. And every body knows, how great Use our incomparable Historian *Mr. Dodwell* has made of the calculated Times of Eclipses, for settling the Times of great Events, which before were, as to this essential Circumstance, almost fabulous. Both *Chronology* and *Geography*, and also the Knowledge of the Sun's and Moon's Motions, so far as they relate to the Constitution of the Kalendar and Year, are necessary to a Divine; and how sadly some otherwise Eminent have blundered, when they meddled with things that relate to these, and border on them, is too apparent.

Nobody, I think, will question the Interest, that Mathematics have in *Painting*, *Music*, and *Architecture*, which are all founded on Numbers: *Perspective*, and the Rules of Light and Shadows, are owing to *Geometry* and *Optics*: And, I think, those Two comprehend pretty near the whole Art of *Painting*, except *Decorum* and *Ordinance*; which are only a due Observance of the History and Circumstances of the Subject you represent: For, by *Perspective*, may be understood the Art of designing the Outlines of your Solid, whether that be a Building, Landskip, or Animal: And the Draught of a Man is really as much the *Perspective* of a Man, as the Draught of a Building is of a Building; tho', for particular Reasons, as because it consists of more crooked Lines, &c. it is hard to reduce the *Perspective* of the former, to the ordinary established Rules.

If *Mathematics* had not reduced *Music* to a regular System, by contriving its *Scales*, it had been no Art, but enthusiastic Rapture, left to the roving Fancy of every Practitioner. This appears by the extraordinary Pains, which the Antients have taken to fit Numbers to Three Sorts of Music, the *Diatonic*,

nic, Chromatic, and Enharmonic: Which if we consider with their Nicety in distinguishing their several *Modes*, we shall be apt to judge, they had something very fine in their *Music*, at least, for moving the Passions with single Instruments and Voices. But *Music* had been imperfect still, had not *Arithmetic* stepped in once more, and *Guido Aretinus*, by inventing the Temperament, making the Fifth False by a certain determined Quantity, taught us to tune our Organs, and intermix all the Three Kinds of the Antients, to which we owe all the regular and noble Harmony of our modern *Music*.

As for *Civil Architecture* (of Military I shall speak afterwards) there is hardly any Part of *Mathematics*, but is some way subservient to it. *Geometry* and *Arithmetic*, for the due Measure of the several Parts of a Building, the Plans, Models, Computation of Materials, Time, and Charges; for ordering right its Arches and Vaults, that they may be both firm and beautiful: *Mechanics*, for its Strength and Firmness, transporting and raising Materials: And *Optics*, for the Symmetry and Beauty. And I would not have any assume the Character of an *Architect* without a competent Skill in all of these. You see that *Vitruvius* requires these, and many more, for making a complete *Architect*. I must own, that should any one set up to practise in any of the fore-mentioned Arts, furnished only with his Mathematical Rules, he would produce but very clumsy Pieces. He, that should pretend to draw by the Geometrical Rules of Perspective, or compose *Music* merely by his Skill in harmonical Numbers, would shew but awkward Performances. In those compos'd Subjects, besides the stiff Rules, there must be Fancy, Genius, and Habit. Yet, nevertheless, these Arts owe their Being to *Mathematics*, as laying the Foundation of their Theory, and affording them Precepts, which, being once invented, are securely rely'd upon

upon by Practitioners. Thus many design, that know not a Tittle of the Reason of the Rules they practise by; and many, no better qualify'd in their way, compose *Musick*, better, perhaps, than he could have done, that invented the *Scale*, and the *Numbers* upon which their Harmony is founded. As *Mathematics* laid the Foundation of these Arts, so they must improve them: And he, that would invent, must be skill'd in Numbers: Besides, it is fit a Man should know the true Grounds and Reasons of what he studies: And he that does so, will certainly practise in his Art with greater Judgment and Variety, where the ordinary Rules fail him.

I proceed now to shew the more immediate Usefulness of *Mathematics* in *Civil Affairs*. To begin with *Arithmetic*, it were an endless Task to relate its several Uses in public and private Business. The Regulation and quick Dispatch of both seem intirely owing to it. The Nations, that want it, are altogether barbarous, as some *Americans*, who can hardly reckon above Twenty. And, I believe, it would go near to ruin the Trade of the Nation, were the easy Practice of *Arithmetic* abolished: For Example, were the Merchants and Tradesmen obliged to make use of no other than the *Roman* way of Notation by Letters, instead of our present. And if we should feel the Want of our *Arithmetic* in the easiest Calculations, how much more in those; that are something harder? as Interest simple and compound, Annuities, &c. in which, it is incredible, how much the ordinary Rules and Tables influence the Dispatch of Business. *Arithmetic* is not only the great Instrument of private Commerce, but by it are (or ought to be) kept the public Accounts of a Nation: I mean those, that regard the whole State of a Commonwealth, as to the Number, Fructification of its People, Increase of Stock, Improvement of Lands and Manufactures, Balance of

Trade, Public Revenues, Coinage, Military Power by Sea and Land, &c. Those that would judge or reason truly about the State of any Nation, must go that way to work, subjecting all the fore-mentioned Particulars to Calculation. This is the true *Political Knowledge*. In this respect the Affairs of a Commonwealth differ from those of a private Family, only in the Greatness and Multitude of Particulars, that make up the Accounts. *Machiavel* goes this way to work in his Account of different Estates. What Sir *William Petty*, and several others of our Countrymen, have wrote in *Political Arithmetic*, does abundantly shew the Pleasure and Usefulness of such Speculations. It is true, for want of good Information, their Calculations sometimes proceed upon erroneous Suppositions: But that is not the Fault of the Art. But what is it the Government could not perform in this way, who have the Command of all public Records?

Lastly, Numbers are applicable even to such things, as seem to be governed by no Rule, I mean such as depend on *Chance*; the Quantity of Probability and Proportion of it in any Two proposed Cases being subject to Calculation as much as any thing else. Upon this depend the Principles of Game. We find Sharpers know enough of this, to cheat some Men that would take it very ill to be thought Bubbles: And one Gamester exceeds another, as he has a greater Sagacity and Readiness in calculating his Probability to win or lose in any proposed Case. To understand the Theory of *Chance* thoroughly, requires a great Knowledge of Numbers, and a pretty competent one of *Algebra*.

The several Uses of *Geometry* are not much fewer than those of *Arithmetic*. It is necessary for ascertaining of Property both in Planes and Solids, or in Surveying and Gauging. By it, Land is sold by the Measure, as well as Cloth: Workmen are paid the

the due Price of their Labour, according to superficial or solid Measure of their Work: And the Quantity of Liquors determined for a due Regulation of their Price and Duty. All which do wonderfully conduce to the easy Dispatch of Business, and the preventing of Frauds and Controversies. I need not mention the measuring Distances, laying down of Plans and Maps of Countries, in which we have daily Experience of its Usefulness. These are some familiar Instances of things, to which *Geometry* is ordinarily applied: Of its Use in *Civil*, *Military*, and *Naval Architecture*, we shall speak afterwards.

From *Astronomy* we have the regular Disposition of our Time, in a due Succession of Years, which are kept within their Limits as to the Return of the Seasons, and the Motion of the Sun. This is no small Advantage for the due Repetition of the same Work, Labour, and Actions. For many of our Public, Private, Military, and Country Affairs, Appointments, &c. depending on the Products of the Ground, and they on the Seasons; it is necessary, that the Returns of them be adjusted pretty near to the Motion of the Sun: And we should quickly find the Inconveniency of a *vague* undetermined Year, if we used that of the *Mahumetans*, whose Beginning, and every Month, wanders through all the Days of ours or the Solar Year, which shews the Seasons. Beside, the adjusting of the Moon's Motion to the Sun's is required for the decent Observation and Celebration of the *Church-Fests* and *Fasts*, according to the antient Custom, and primitive Institution; and, likewise, for the knowing of the Ebbing and Flowing of the Tides, the Spring, and Neap Tides, Currents, &c. So that whatever some People may think of an *Almanac* where all these are set down, it is oftentimes the most useful Paper that is published the same Year with it: Nay, the
Nation

Nation could better spare all the voluminous Authors in the *Term-Catalogue*, than that single Sheet. Besides, without a regular Chronology, there can be no certain History; which appears by the Confusion amongst Historians before the right Disposition of the Year, and, at present, among the *Turks*, who have the same Confusion in their History as in their Kalendar. Therefore, a Matter of such Importance might well deserve the Care of the *Great Emperor*, to whom we owe our present Kalendar; who was himself a great Proficient in *Astronomy*. *Pliny* has quoted several things from his Books of the *Rising and Setting of the Stars*, *Lib. XVIII. cap. 25, 26, &c.* and *Lucan* makes him say,

————— *Media inter praelia semper
Stellarum, cœlique plagis, superisque vacavi.*

x The *Mechanics* have produced so many useful Engines, subservient to Conveniency, that it would be a Task too great to relate the several Sorts of them: Some of them keep Life itself from being a Burden. If we consider such, as are invented for raising Weights, and are employed in Building, and other great Works, in which no Impediment is too great for them; or *Hydraulic* Engines for raising of Water, serving for great Use and Comfort to Mankind, where they have no other way to be supply'd readily with that necessary Element; or such as, by making Wind and Water work for us, save animal Force, and great Charges, and perform those Actions, which require a vast Multitude of Hands, and without which every Man's Time would be too little to prepare his own Aliment, and other Necessaries; or those Machines, that have been invented by Mankind for Delight and Curiosity, imitating the Motions of Animals, or other Works of Nature; we shall have Reason to admire and extol so excellent an Art. What shall we say of

of the several Instruments, which are contrived to measure Time? We should quickly find the Value of them, if we were reduced to the Condition of those barbarous Nations that want them. The *Pendulum Clock*, invented and completed by that famous Mathematician Monsieur *Huygens*, is an useful Invention. Is there any thing more wonderful, than several *Planetary Machines*, which have been invented to shew the Motions of the heavenly Bodies, and their Places at any time? Of which the most ingenious, according to the exactest Numbers, and true System, was made by the same M. *Huygens*: To which we may very justly apply *Claudian's* noble Verses upon that of *Archimedes*:

*Jupiter in parvo cùm cerneret æthera vitro,
Risit, & ad superos talia dicta dedit:
Hucine mortalis progressa potentia curæ?
Jam meus in fragili luditur orbe labor.
Fura poli, rerumque fidem, legesque Deorum
Ecce Syracusius transtulit arte senex.
Inclusus variis famulatur spiritus astris,
Et vivum certis motibus urget opus.
Percurrit proprium mentitus Signifer annum,
Et simulata novo Cynibia mense redit.
Jamq; suum volvens audax industria mundum
Gaudet, & humanâ sidera mente regit.
Quid falso insontem tonitru Salmonea miror?
Æmula naturæ parva reperta manus.*

Here I ought to mention the *Sciatberical Instruments*, for want of which there was a time, when the *Grecians* themselves were forced to measure the Shadow, in order to know the Hour; and, as *Pliny* (*cap. ult. lib. VII.*) tells us, the *Romans* made use of an erroneous Sun-dial for Ninety-nine Years, till *Q. Marcius Philippus*, their Censor, set up a better; which, no doubt, at that time, was thought a Jewel.

Jewel. And, at last, that famous Pyramid was set up in the *Campus Martius*, to serve for a Gnomon to a Dial marked on the Street. To this Sort of Engines ought to be referred *Spheres, Globes, Astrolabes, Projections of the Sphere, &c.* These are such useful and necessary things, that alone may recommend the Art, by which they are made. For, by these, we are able in our Closet to judge of the celestial Motions, and to visit the most distant Places of the Earth, without the Fatigue and Danger of Voyages; to determine concerning their Distance, Situation, Climate, Nature of the Seasons, Length of their Days, and their Relation to the celestial Bodies, as much as if we were Inhabitants. To all these I might add those Instruments, which the *Mathematicians* have invented to execute their own Precepts, for making *Observations* either by Sea or Land, *Surveying, Gauging, &c.*

The *Catoptrics* and *Dioptrics* furnish us with Variety of useful Inventions, both for the promoting of Knowledge, and the Conveniencies of Life; whereby Sight, the great Instrument of our Perception, is so much improved, that neither the Distance nor the Minuteness of the Object are any more Impediments to it. The *Telescope* is of so vast Use, that, besides the delightful and useful Purposes it is apply'd to here below, as the descrying Ships, and Men, and Armies, at a Distance, we have, by its means, discovered new Parts of the Creation, fresh Instances of the surprising Wisdom of the adorable Creator. We have, by it, discovered the *Satellites of Jupiter*, the *Satellites and Ring of Saturn*, the Rotation of the Planets about their own Axes; besides other Appearances, whereby the System of the World is made plain to Sense, as was before to Reason. The *Telescope* has also improved the Manner of *Astronomical Observations*, and made them much more accurate, than it was possible for them

as we find by the help of the Telescope^{to}

to be before. And these Improvements in *Astronomy*, have brought along with them (as ever) correspondent Improvements in *Geography*. From the Observation of *Jupiter's Satellites*, we have a ready Way to determine the Longitude of Places on the Earth. On the other hand, the *Microscope* has not been less useful in helping us to the Sight of such Objects, as by their Minuteness escape our naked Eye. By it Men have pursued Nature into its most retired Recesses; so that now it can hardly any more hide its greatest Mysteries from us. How much have we learned by the Help of the *Microscope* of the Contrivance and Structure of animal and vegetable Bodies, and the Composition of Fluids and Solids? But if these *Sciences* had never gone further, than by their single *Specula* and *Lentes* to give those surprising Appearances of Objects, and their Images, and to produce Heat unimitable by our hottest Furnaces, and to furnish infallible, easy, cheap, and safe Remedies for the Decay of our Sight arising commonly from old Age, and for Purblindness, they had merited the greatest Esteem, and invited to the closest Study: Especially, if we consider, that such as naturally are almost blind, and either know not their nearest Acquaintance at the Distance of a Room's Breadth, or cannot read, in order to pass their Time pleasantly, are, by Glasses adapted to the Defect of their Eyes, set on a Level again with those that enjoy their Eye-sight best, and that without Danger, Pain, or Charge.

Again, *Mathematics* are highly serviceable to a Nation in *Military Affairs*. I believe this will be readily acknowledged by every Body. The Affairs of War take in Number, Space, Force, Distance, Time, &c. (Things of *Mathematical* Consideration) in all its Parts, in *Tactics*, *Castrametation*, *Fortifying*, *Attacking*, and *Defending*. The Antients had more Occasion for Mechanics in the Art of War than we

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have;

have; Gunpowder readily producing a Force far exceeding all the Engines, they had contriv'd for Battery. And this, I reckon, has lost us a good Occasion of improving our Mechanics; the Cunning of Mankind never exerting itself so much, as in their Arts of destroying one another. But, as Gunpowder has made Mechanics less serviceable to War; it has made *Geometry* more necessary: There being a Force or Resistance in the due Measures and Proportions of the Lines and Angles of a Fortification, which contribute much towards its Strength. This Art of *Fortification* has been much study'd of late, but I dare not affirm, that it has attained its utmost Perfection. And tho', where the Ground is regular, it admits but of small Variety, the Measures being pretty well determined by *Geometry* and Experience, yet where the Ground is made up of natural *Strengths* and *Weaknesses*, it affords some Scope for Thinking and Contrivance. But there is another much harder Piece of *Geometry*, which Gunpowder has given us Occasion to improve, and that is the Doctrine of Projectiles; whereon the Art of *Geometry* is founded. Here the *Geometers* have invented a beautiful Theory, and Rules and Instruments, which have reduced the Casting of Bombs to great Exactness. As for *Tactics* and *Castrametation*, *Mathematics* retain the same Place in them as ever. And some tolerable Skill in these is necessary for *Officers*, as well as for *Engineers*. An *Officer*, that understands Fortification, will, *ceteris paribus*, much better defend his Post, as knowing, wherein its Strength consists, or make use of his Advantage to his Enemy's Ruin, than he that does not. He knows, when he leads never so small a Party, what his Advantages and Disadvantages in Defending and Attacking are, how to make the best of his Ground, &c. And hereby can do truly more Service than another of as much

Courage, who, for want of such Knowledge, it may be, throws away himself, and a Number of brave Fellows under his Command; and it is well, if the Mischief reaches no further. As for a competent Skill in *Numbers*, it is so necessary to *Officers*, that no Man can be safely trusted with a Company, that has it not. All the Business is not to fire *Musquets*; the managing of Affairs, the dealing with Agents, &c. happen more frequently. And the higher the Command is, the more Skill in all the aforesaid things is required. And I dare appeal to all the Nations in *Europe*, whether, *cæteris paribus*, Officers are not advanced in Proportion to their Skill in *Mathematical Learning*; except, that sometimes *Great Names* and *Quality* carry it; but still so, as that the Prince depends upon a Man of *Mathematical Learning*, that is put as Director to the *Quality*, when that Learning is wanting in it.

Lastly, *Navigation*, which is made up of *Astronomy* and *Geometry*, is so noble an Art, and to which Mankind owes so many Advantages, that, upon this single Account, those excellent Sciences deserve most of all to be studied, and merit the greatest Encouragement from a Nation, that owes to it both its Riches and Security. And not only does the common Art of *Navigation* depend on *Mathematics*, but whatever Improvements shall be made in the *Architectura Navalis*, or Building of Ships, whether they are designed for Merchant-Ships, or Ships of War, whether swift running, or bearing a great Sail, or lying near the Wind, be desired, these must all be the Improvements of *Geometry*. *Ship-Carpenters*, indeed, are very industrious; but in these things they acknowledge their Inability, confess that their best Productions are the Effects of Chance, and implore the *Geometer's* Help. Nor will common *Geometry* do the Business; it requires the most abstruse to determine the different Sections of
D 2 a Ship,

a Ship, according as it is designed for any of the
aforeſaid Ends. A *French Mathematician P. le*
Hoſte has lately endeavoured ſomething in this
way : And tho' it is not free from Errors, as re-
quiring a fuller Knowledge in *Geometry* ; yet is the
Author much to be commended for this, as having
bravely deſigned, and pay'd the Way for other Ma-
thematicians ; and alſo for the former and bigger
Part of his Book, wherein he brings to a System
the Working of Ships, and the *Naval Tactics*, or
the regular Diſpoſition of a Fleet in Attacking,
Fighting, and Retreating, according to the differ-
ent Circumſtances of Wind, Tides, &c.

The great Objection, that is made againſt the
Neceſſity of *Mathematics*, in the fore-mentioned
great Affairs of *Navigation*, the Art *Military*, &c.
is, that we ſee thoſe Affairs are carried on and ma-
naged by ſuch, as are not great Mathematicians ;
as Seamen, Engineers, Surveyors, Gaugers, Clock-
makers, Glaſs-grinders, &c. and that the Mathe-
maticians are commonly ſpeculative retired, ſtu-
dious Men, that are not for an active Life and
Buſineſs, but content themſelves to ſit in their Stu-
dies, and pore over a *Scheme*, or a *Calculation*. To
which there is this plain and eaſy Answer : The Ma-
thematicians have not only invented and ordered all
the Arts above-mentioned, by which thoſe grand
Affairs are managed ; but have laid down Precepts,
contrived Inſtruments and Abridgments ſo plainly,
that common Artificers are capable of practiſing
by them, tho' they underſtand not a Tittle of the
Grounds, on which the Precepts are built. And
in this they have conſulted the Good and Neceſſi-
ties of Mankind. Thoſe Affairs demand ſo great
a Number of People to manage them, that it is
impoſſible to breed ſo many good or even tolerable
Mathematicians. The only thing then to be done
was to make their Precepts ſo plain, that they might
be

be understood and practised by a Multitude of Men. This will best appear by Examples. Nothing is more ordinary than Dispatch of Business by common *Arithmetic*, by the *Tables of simple and compound Interest, Annuities, &c.* Yet how few Men of Business understand the Reasons of common *Arithmetic*, or the Contrivance of those Tables, now they are made; but securely rely on them as true. They were the good and the thorough Mathematicians, that made those Precepts so plain, and calculated those Tables, that facilitate the Practice so much. Nothing is more universally necessary, than the measuring of Plains and Solids: And it is impossible to breed so many good Mathematicians, as that there may be one, that understands all the *Geometry* requisite for Surveying, and Measuring of *Prisms* and *Pyramids*, and their Parts, and measuring *Frustums* of *Conoids* and *Spheroids*, in every Market-Town, where such Work is necessary: The Mathematicians have therefore inscrib'd such Lines on their common Rulers, and Slipping Rulers, and adapted so plain Precepts to them, that every Country-Carpenter, and Gauger, can do the Business accurately enough; though he knows no more of those Instruments, Tables, and Precepts he makes use of, than a Hobby-horse. So in *Navigation*, it is impossible to breed so many good Mathematicians, as would be necessary to sail the hundredth Part of the Ships of the Nation. But the Mathematicians have laid down so plain and distinct Precepts, calculated necessary Tables, and contrived convenient Instruments, so that a Sea-man, that knows not the Truths, on which his Precepts and Tables depend, may practise safely by them. They resolve Triangles every Day, that know not the Reason of any one of their *Operations*. Seamen in their
Calcu-

Calculations make use of ~~artificial~~ *Numbers*, or *Logarithms*, that know nothing of their Contrivance: And indeed all those great Inventions of the most famous Mathematicians had been almost useless for those common and great Affairs, had not the Practice of them been made easy to those who cannot understand them. From hence it is plain, that it is to those *Speculative Retir'd Men*, we owe the Rules, the Instruments, the Precepts for using them, and the Tables which facilitate the Dispatch of so many great Affairs, and supply Mankind with so many Conveniencies of Life. They were the Men, that taught the World to apply *Arithmetic*, *Astronomy*, and *Geometry*, to *Sailing*, without which the Needle would be still useless. Just the same way in the other Parts of *Mathematics*, the Precepts that are practised by Multitudes, without being understood, were contriv'd by some few great *Mathematicians*.

Since then it has been shewn, how much *Mathematics* improve the Mind, how subservient they are to other Arts, and how immediately useful to the Commonwealth, there needs no other Arguments or Motives to a Government, to encourage them. This is the natural Conclusion from these Premises. *Plato*, in his *Republic*, (*lib. VII.*) takes care, *That, whoever is to be educated for Magistracy, or any considerable Post in the Commonwealth, may be instructed first in Arithmetic, then in Geometry, and thirdly in Astronomy.* And however necessary those Arts were in *Plato's* time, they are much more so now: The Arts of War and Trade requiring much more the Assistance of those *Sciences* now, than they did then: as being brought to a greater Height and Perfection. And accordingly we see, these *Sciences* are the particular Care of Princes, that design to raise the Force

Force and Power of their Countries. It is well known, that this is none of the least Arts, whereby the *French King* has brought his Subjects to make that Figure at Sea, which they at this Time do; I mean, the Care He takes for Educating those appointed for Sea-service in *Mathematical Learning*. For in the *Ordonnance Marine*, Title VIII. 'He orders, that there be Professors
 ' to teach Navigation publickly in all the Sea-port
 ' Towns, who must know *Designing*, and teach it
 ' to their Scholars, in order to lay down the Appearances of Coasts, &c. They are to keep
 ' their Schools open, and read four times a Week
 ' to the Seamen, where they must have Charts,
 ' Globes, Spheres, Compasses, Quadrants, Astralabes, and all Books and Instruments necessary
 ' to teach their Art. The Directors of Hospitals
 ' are obliged to send thither yearly two or three
 ' of their Boys to be taught, and to furnish them
 ' with Books and Instruments. Those Professors
 ' are oblig'd to examine the Journals deposited
 ' in the Office of Admiralty, in the Place of their
 ' Establishment; to correct the Errors in Presence
 ' of the Seamen, and to restore them within a
 ' Month,' &c. King *Charles* the Second, who well understood the Importance of Establishments of this Nature, founded one such School in *Christ's Hospital, London*; which, I believe, is inferior to none of the *French*: But 'tis to be wished there were many more such. His present Majesty, during the Time of the late War, established a *Mathematical Lecture* to breed up Engineers and Officers, as knowing very well the Importance thereof. And this continued some time after the *Peace*. And it is worthy the Consideration of the *Wisdom* of the Nation, whether the restoring and continuing this, even in *Peace*, be not expedient for the breeding
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of Engineers, who are so useful and valuable, and so difficult to be had in Time of War, and so little dangerous in Times of Peace.

Besides the Crowd of *Merchants, Seamen, Surveyors, Engineers, Ship-carpenters, Artisans, &c.* that are to be instructed in the Practice of such Parts of *Mathematics*, as are necessary to their own Business respectively, a competent Number of able *Mathematicians* ought to be entertained, in order to apply themselves to the Practice; not only to instruct the former Sort, but likewise to remove those Obstacles, which such, as do not think beyond their common Rules, cannot overcome. And no doubt it is no small Impediment to the Advancement of Arts, that *Speculative Men*, and good *Mathematicians*, are unacquainted with their particular Defects, and the several Circumstances in them, that render things *practicable* or *impracticable*. But if there were public Encouragement, we should have skilful Mathematicians employed in those Arts, who would certainly find out and remedy the Imperfections of them. The present Lords Commissioners of the Admiralty, knowing that there are still two great *Desiderata* in Navigation, to wit, *The Theory of the Variation of the magnetical Needle*, and a *Method of finding out the Longitude of any Place*, that may be practicable at Sea by Seamen, and being sensible, of what Importance it would be to find out either of them, have employed a very fit Person, the ingenious Mr. *Halley*, who has joined an intimate Acquaintance in the Practice, to a full and thorough Knowledge of the more abstruse Parts of *Mathematics*. And now that he is returned, it is not doubted, but he will satisfy those that sent him, and, in due time, the World too, with his Discoveries in both those Particulars, and in many

many other that he has had Occasion to make. And where a long Series of Observations and Experiments is necessary, he has, no doubt, laid such a Foundation, as that After-Observers may gradually perfect them. If it were not for more than the Correcting the Situation of the Coasts where he touched, and by them others, whose Relation to the former is known, the Nation is more than triply paid: And those who sent him, have, by this Mission, secured to themselves more true Honour, and lasting Fame, than by Actions, that, at first View, appear more magnificent.

The next thing that is necessary for the Improvement of *Mathematical Learning*, is, That Mathematics be more generally studied at our *Universities* than hitherto they have been. From those Seminaries the State justly expects and demands Those who are acquainted both with the *Speculation* and *Practice*. In those are all the Encouragements to them imaginable, Leisure and Assistance. There are still at hand Books and Instruments; as also other Scholars that have made equal Progress, and may be Comrades in Study; and the Direction of the Professors. There are also in Perfection all the Incitements to this Study; and especially an Acquaintance with the Works of the Antients, where this *Learning* is so much recommended. There other Faculties are studied, to which it is subservient. There also are the Nobility and Gentry bred; who, in due time, must be called to their Share in the Government of the *Fleets*, *Army*, *Treasury*, and other public Employments, where *Mathematical Learning* is absolutely necessary, and, without which, they, tho' of never so great natural Parts, must be at the Mercy and Discretion of their Servants and De-

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puties ;

puties ; who will first cheat them, and then laugh at them. And not only public Employments, but their private Concerns, demand Mathematical Knowledge. If their Fortunes lie in Woods, Coal, Salt, Manufactures, &c. the Necessity of this Knowledge is open and known : And, even in Land Estates, no Undertaking for Improvement can be securely relied upon without it. It not only makes a Man of Quality and Estate his whole Life more illustrious, and more useful for all Affairs, (as *Hippocrates* says, Ἰσοτὴς δὲ μελέτω σοὶ, ὦ παῖ, Γεωμετρικῆς, καὶ Ἀριθμητικῆς· ἡ γὰρ μόνον σέο καὶ τὸν βίον εὐκλεία καὶ ἐπὶ πολλὰ χρήσιμον ἐς ἀνθρώπινην μοῖρην ἐπιτέλει, ἀλλὰ καὶ τὴν ψυχὴν δεξιέρην τε καὶ τιλαυσιέρην, &c.) but in particular, it is the best Companion for a Country Life. Were this once become a fashionable Study, (and the *Mode* exercises its Empire over Learning as well as other things) it is hard to tell, how far it might influence the Morals of our Nobility and Gentry, in rendering them serious, diligent, curious ; taking them off from the more fruitless and airy Exercises of the Fancy, which they are apt to run into.

The only Objection I can think of, that is brought against these Studies, is, That Mathematics require a particular Turn of Head, and a happy Genius, that few People are Masters of ; without which all the Pains bestowed upon the Study of them are in vain : They imagine, that a *Man must be born a Mathematician*. I answer, That this *Exception* is common to Mathematics and other Arts. That there are Persons that have a particular Capacity and Fitness to one more than another, every body owns : And, from Experience, I dare say, it is not in any higher Degree true concerning Mathematics, than the others. A Man of good Sense and Application is the Person that
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is by Nature fitted for them ; especially if he begins betimes : And, if his Circumstances have been such, that this did not happen, by prudent Direction the Defect may be supplied, as much as in any Art whatsoever. The only Advantage this Objection has, is, That it is on the Side of Softness and Idleness, those powerful Allies !

There is nothing further remains, Sir, but that I give you my Thoughts in general concerning the *Order* and *Method* of studying *Mathematics* ; which I shall do very briefly, as knowing that you are already acquainted with the best Methods ; and others with you may have them easily from the best and ablest Hands.

First, then, I lay down for a Principle, That nobody at an *University* is to be taught the Practice of any Rule without the true and solid Reason and Demonstration of the same. Rules without Demonstration must and ought to be taught to *Seamen*, *Artisans*, &c. as I have already said ; and Schools for such People are fit in Sea-ports and Trading-Towns ; but it is far below the Dignity of an *University*, which is design'd for solid and true Learning, to do this. It is from the Universities that they must come, who are able to remedy the Defects of the Arts ; and therefore nothing must be taken on Trust there. *Seamen* and *Surveyors*, &c. remember their Rules, because they are perpetually practising them ; but *Scholars*, who are not thus employ'd, if they know not the Demonstration of them, presently forget them.

Secondly, No Part of *Mathematics* ought to be taught by *Compendiums*. This follows from the former. *Compendiums* are fit to give a general and superficial Knowledge, not a thorough one. It is Time, and not the Bulk of Books, we ought to be sparing of : And I appeal to any Person of

Experience, whether solid Knowledge is not acquir'd in shorter time by Books treating fully of their Subjects, than by Compendiums and Abridgments.

From hence it follows, that the *Elements* of *Arithmetic* and *Geometry* are to be taught. *Euclid*, in his Thirteen Books of Elements, gives us both: but our present Way of Notation supercedes some of those of *Arithmetic*, as demonstrating the Rules from the Operations themselves. There remain then the first Six Books for the *Geometry* of *Planes*, and the last Three for *Stereometry*. The rest ought to be read in their own Place, for the Perfection of *Arithmetic*. In teaching these, Care ought to be taken to make use of such Examples, as suit with the Condition of the Scholar: For Instance, *Merchants Accompts* and *Affairs* for Examples of the Operations of *Arithmetic*, to one that is afterwards to have a Concern that way; whereas, to a Man of the first Quality, Examples from the *Increase* and *Decrease* of the *People*, or from *Land* or *Sea Force*, and from the *Tactics*, ought to be proposed. For, it is certain, nothing makes one tir'd sooner, than the frivolous and trifling Examples, that are commonly brought for the Exercise of the Rules of *Arithmetic* and *Geometry*; tho' this is common to them with the other Arts, as *Grammar*, *Logic*, &c.

The Manner of Writing of the Mathematicians of This and the former Age makes *Trigonometry*, with the Manner of Constructing its Tables, &c. almost *Elementary*: And the *Practical Geometry*, commonly so call'd, is very fit to come next, as an elegant Application of the *Elements* of *Geometry* to Business, as *Surveying*, *Gauging*, &c.

After the Elements of *Spherics*, which are perfectly well-handled by *Theodosius*, a full Insight into the Principles of *Astronomy* will be necessary.

Mechanics

Mechanics come next to be read, which are the Ground of a great Part of natural Learning; and, afterwards, *Optics*, *Catoptrics*, and *Dioptrics*.

But none of these, except the Elements, can be fully understood, until one is pretty well skill'd in *Conic Sections*: And all these are made more easy by some tolerable Skill in *Algebra*, and its Application to *Geometry*.

These Foundations being laid, any one may, with great Ease, pursue the Study of the Mathematics, as his Occasions require; either in its abstract Parts, and the more *recondite Geometry*, and its Application to Natural Knowledge; or in *Mechanics*; by prosecuting the *Statics*, *Hydrostatics*, *Ballistics*, &c.: Or in *Astronomy*, by its Application to *Geography*, *Navigation*, *Gnomonics*, *Astro-labes*, &c. But, in most of these, a particular Order is not necessary: Any one may take That first, which he is most inclined to.

I shall not offer you any Advice concerning the Choice of Books; but refer you (if you want any) to the Direction of those who are eminent among you in this Part of Learning. I ask your Pardon for the Omission of *Ceremony* in these Papers; having followed rather the ordinary Way of *Essay*, than *Letter*. And, wishing you good Success in your Studies, I am,

S I R,

Your Friend and Servant.

25 Novemb.
1700.

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